EFFECTS OF FATIGUE ON STRENGTH AND RAPID FORCE CHARACTERISTICS BETWEEN TRADITIONAL AND EXPLOSIVE RESISTANCE-TRAINED MALES

By

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TRAINED MALES

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PURPOSE: Examine the effects of fatigue on maximal strength and rapid force between traditional (TRT) and explosive (ERT) resistance-trained males, following upper (UE) and lower extremity (LE) fatigue protocols. METHODS: Twelve TRT (mean±SD: age=24.5±2.94years, height=178.54±5.64cm, mass=93.28±15.07kg) and eight ERT (mean±SD: age=22±2.39years, height=177.8±5.43cm, mass=80.74±7.22kg) males visited the laboratory on 2 occasions, separated by 2-3 days. The first visit included classifying participants as TRT or ERT, determined by their self-reported training status. Participants were familiarized with the isometric and isokinetic maximal voluntary contractions (MVCs) of the UE [Elbow Flexors (EF) and Extensors (EE)] and LE [Knee Flexors (KF) and Extensors (KE)] testing protocols. During the second visit, participants performed the isokinetic protocols (50 repetitions at $180^{\circ}\cdot s^{-1}$) for the UE and LE, in randomized order, with a 20 minute rest period between protocols. Prior to (Pre) and immediately following (Post) the protocols, isometric and isokinetic MVCs were completed in order to assess peak torque (PT), peak velocity (Vmax), acceleration (ACC), and fatigue index (FI). Separate 2-way mixed factorial ANOVAs were performed for each dependent variable. An alpha level of $p \leq 0.05$ was utilized to determine statistical significance. RESULTS: There was no significant group × time interaction for ACC (p=0.196-0.903), PT (p=0.128-0.429), Vmax (p=0.150-0.996), nor a group × muscle interaction for FI (p=0.095-0.536). However, a main effect for group (p=0.030) was revealed in which the TRT group had a higher PT compared to the ERT group for the EF. Furthermore, significant main effects for time ($p \leq 0.002$) was observed, in which ACC, PT, and Vmax were significantly lower a Post compared to Pre for all muscle groups except for PT of the knee extensors. Additionally, FI was greater in the EF (p=0.001-0.016) compared to all other muscles for ACC and Vmax; however, EF FI of PT was greater only when compared to the knee extensors (p=0.022). CONCLUSIONS: An isokinetic fatigue protocol of the UE and LE had similar effects on TRT and ERT individuals. Although specific muscles were affected differently, it is possible this is due to the lack of specificity with the isokinetic testing modality and the participant training status.

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CHAPTER I

INTRODUCTION

Resistance-training has been shown to elicit several essential benefits related to human performance, including but not limited to muscular hypertrophy, increased strength, power, and speed (Hooper et al., 2013). Manipulation of resistance-training characteristics (i.e., number of sets, repetitions, length of rest periods, and external load) may produce differential adaptive responses in skeletal muscle, as it may be sensitive to the acute and chronic stressors associated with resistance-training. These responses are influenced by the structure and implementation of resistance activity, as well as the level of training (i.e., beginner, intermediate, or advanced) for the individuals involved (Abernethy, Jurimae, Logan, Taylor, & Thayer, 1994). Consequently, there appears to be a specific relationship between modes of training (i.e., muscular strength, power, and endurance) and the adaptive response (Campos et al., 2002).

Although resistance-training can serve many purposes, it is suggested that the “specificity principle” may allow for better overall performance because the exercise prescription is similar to the athletic movements that would be performed by the individual (Murray et al., 2007; Pereira & Gomes, 2003). Recent examinations showed that the greatest gains in force and power production are seen at movement velocities comparable to that of training (Murray et al., 2007; Pereira & Gomes, 2003). This is further demonstrated by Behm (1995), who revealed, in order to maintain high velocity specific adaptations in a power training program, the speed of contraction must be high/fast ($\geq 240^{o} \cdot s^{-1}$) (Murray et al., 2007)(Murray et al., 2007; Pereira & Gomes, 2003). Additionally, studies in younger adults have shown differential effects of explosive (ERT) versus heavy resistance-training with regard to the development of muscle power and the ability to generate force rapidly (Caserotti, Aagaard, Buttrup Larsen, & Puggaard, 2008; R. U. Newton, Kraemer, & Haekkinen, 1999). Newton et al. (1999) found that maximal power training, involving explosive movements, was more effective than traditional (TRT) resistance-training for increasing vertical jump ability. Although power has also been shown to increase through TRT (Channell & Barfield, 2008; Jozsi, Campbell, Joseph, Davey, & Evans, 1999), the specificity of ERT may have a greater influence on the ability to apply force. Specifically, TRT tends to focus on higher intensity at a lower-speed (Channell & Barfield, 2008), whereas ERT can be defined as movements (i.e., snatch, hang clean, power clean, and push jerk) in which maximum or near maximum rates of force development are attained (Stone & O'Bryant, 1987). Several components of ERT contribute directly to explosive performance including the ability to accelerate objects through the production of high velocity movements, attaining a high peak rate of force development, and the associated explosive strength ,with high acceleration capabilities (Caserotti et al., 2008).

Previous authors have attempted to understand specific training adaptations related to increases in strength and power production (Fielding et al., 2002; Judge, Moreau, & Burke, 2003). For example, Fielding et al. (2002), found that a 16-week ERT program, involving the leg press and knee extension exercises, significantly improved peak power, and was equally efficient at increasing muscle strength compared to TRT. In addition to prior training studies, previous authors have assessed neuromuscular differences between individuals with different training backgrounds (Häkkinen & Keskinen, 1989; Lattier, Millet, Maffiuletti, Babault, & Lepers, 2003). Specifically, Lattier et al. (2003) investigated neuromuscular differences between endurance-trained, power-trained, and sedentary subjects in which power- and endurance-trained individuals had greater maximal strength compared to untrained subjects. Interestingly, Lattier et al. (2003) observed differential responses to the functional performance measures (i.e., squat jump and counter-movement jump height). Specifically, the power-trained group performed these movements to a greater ability compared to the other two groups (Lattier et al., 2003). Additionally, Häkkinen and Keskinen (1989) examined muscle cross-sectional area and characteristics of force production in elite strength-trained athletes, sprinters, and endurance-trained athletes. The result of that study revealed that when maximal forces were related to cross-sectional area of the muscle, the strength-athletes had slightly greater values than the sprinters, while both of those groups had significantly greater values than the endurance-athletes (Häkkinen & Keskinen, 1989). Although much is known in regards to muscular adaptations following resistance-training interventions such as increased maximal force (R. U. Newton et al., 2002), power (Murray et al., 2007; R. U. Newton et al., 2002), hypertrophy (McCaulley et al., 2009; Schuenke et al., 2012), and an increase in Type II fibers (Schuenke et al., 2012), as well as comparing trained populations with sedentary populations (Alway, MacDougall, Sale, Sutton, & McComas, 1988; M. J. Newton, Morgan, Sacco, Chapman, & Nosaka, 2008), it may be useful to investigate the specific fatigue-induced responses of maximal and rapid force characteristics between different resistance-trained groups to further elucidate these muscular adaptations related to specificity of training.

Due to the training specificity and the aforementioned observed training adaptations of TRT and ERT, it may be of interest to examine the potential differences in fatigue-induced responses to various performance measures, [(i.e., peak torque (PT), peak velocity (Vmax), acceleration (ACC), and Fatigue Index (FI%)] between two resistance-trained groups. Specifically, fatigue has been defined as any reduction in the force-producing capacity of a muscle during a maximal voluntary contraction (Gandevia, 1992), as well as an inability to maintain a given, maximal strength level, when performing repeated maximal isokinetic contractions (Mathiassen, 1989). This reduction in force-producing capacity may lead to deficits in subsequent muscular performance, thus hindering physical ability post-exercise. For example, Hakkinen (1993) observed deficits in maximal isometric force in the knee extensors following a high-intensity back squat protocol. Additionally, Chiu, Fry, Schilling, Johnson, and Weiss (2004) revealed decreases in maximal force of the knee extensor muscle group following a back squat protocol, explosive in nature. Conchola, Thiele, Palmer, Smith, and Thompson (2015a) reported similar deficits in maximal and rapid strength immediately following two work-matched back squat protocols in which differential recovery patterns were observed between peak torque (PT) and rate of torque development (RTD) within 30 minutes.

Similarly, Clarkson, Kroll, and Melchionda (1982) showed a decrease in knee extensor maximal force following a dynamic isokinetic protocol of the lower extremity. In addition, Clarkson et al. (1982) showed a decrease in elbow flexor maximal force following a dynamic isokinetic protocol of the upper extremity. Furthermore, Bilodeau, Erb, Nichols, Joiner, and Weeks (2001) have shown decreased force-generating capacity of the elbow flexors following a sustained maximal isometric contraction protocol. Moreover, Nguyen et al. (2009) observed a significant deficit in PT and rate of velocity development (RVD) following a dynamic isokinetic protocol consisting of eccentric muscle actions of the elbow flexors. Linnamo, Bottas, and Komi (2000) revealed dramatic deficits in concentric force of the elbow flexors following a bout of dynamic isokinetic muscle actions. Taken together, the effects of a dynamic fatigue protocol may result in acute deficits in maximal strength and rapid force characteristics of the lower extremity as well as the upper extremity in resistance-trained individuals.

Although a majority of muscle fatigue literature is based upon the use of intermittent and/or sustained isometric contractions (Bilodeau et al., 2001; Conchola, Thiele, Palmer, Smith, & Thompson, 2015b; Conchola, Thompson, & Smith, 2013; Corcos, Jiang, Wilding, & Gottlieb, 2002; Pääsuke, Ereline, & Gapeyeva, 1999), the nature of most motor tasks in athletic and voluntary physical activities may lend itself, rather, to the assessment of dynamic muscle actions in order to examine muscle fatigue (Izquierdo et al., 2009). Traditionally, ERT consists of the previously mentioned power exercises (i.e., snatch, hang clean, power clean, and push jerk) at a percentage of their one repetition maximum (1RM), with a goal of 1-2 repetitions for a single-effort (80-90% 1RM) or 3-5 repetitions for multiple effort (75-85% 1RM) events. Typically this style of training involves performing these types of movements in the initial stages of a training session, followed by non-power movements and subsequent assistance lifts (Baechle, Earle, & National Strength & Conditioning Association (U.S.), 2008). In contrast, TRT has been characterized as a combination of strength (≤6 repetitions at ≥85% 1RM) and hypertrophy (6-12 repetitions at 67-85% 1RM) movements (i.e., back squat, bench press, deadlift, bent over row, and shoulder press). Specific to this type of training, the core lifts are performed at the beginning of a training session followed by assistance exercises and subsequent isolation movements in which specific muscle groups may be targeted (Baechle, Earle, & National Strength & Conditioning Association (U.S.), 2000). The ability to identify significant differences in strength and rapid force characteristics between two dissimilarly trained groups following a dynamic isokinetic fatigue protocol, may lead to further understanding of specific acquired adaptations to training. Therefore the purpose of this study was to examine the effects of fatigue on maximal strength and rapid force characteristics between TRT and ERT males after performing a dynamic fatigue protocol. The present author hypothesized that; (1) the TRT group will produce a higher PT than the ERT group, (2) the ERT group will have a faster ACC and produce a higher Vmax than the TRT group, (3) the TRT group will retain higher strength measures after the protocol, and (4) the ERT group will retain higher rapid measures after the protocol.

CHAPTER II

METHODS

2.1. Research Design

This study used quantitative measures to offer descriptive research. Through this research, the information acquired provided data about the effects of fatigue on strength and rapid force characteristics for individuals who participated as well as group information. The dependent variables measured were peak torque (PT), peak velocity (Vmax), acceleration (ACC), and fatigue index (FI%) of PT, Vmax, and ACC from Pre to Post. Independent variables include the traditional (TRT) and explosive (ERT) resistance-trained groups and the muscles used knee extensors (KE), knee flexors (KF), elbow extensors (EE), and elbow flexors (EF).

2.2. Participants

Twelve TRT (mean ± SD: age=24.5±2.94 years, height=178.54±5.64 cm, mass=93.28±15.07 kg) and eight ERT (mean ± SD: age=22±2.39 years, height=177.8±5.43 cm, mass=80.74±7.22 kg) males participated in this study. All participants consistently engaged in a TRT (mean ± SD: 4.29±2.16 years, 4.58±0.52 days per week) or ERT (mean ± SD: 3.56±1.69 years, 4.75±0.71 days per week) program ≥3 times per week for a minimum of 6 months before the study. Using convenience sampling, participants were recruited via classrooms with a verbal script, hanging flyers, and word of mouth. Participants were split into either the TRT or ERT group based on how they reported their training status and typical exercise routine on the health history questionnaire. Participants who reported any musculoskeletal injuries of the upper or lower extremities within 12 months before testing were excluded. The study was approved by the University Institutional Review Board for human subject's research, and before any testing; each participant completed an informed consent document and health history questionnaire.

2.3. Procedures

Participants visited the laboratory on 2 separate occasions. The first visit was designated as familiarization (day 1), where participants completed a health history questionnaire and signed the informed consent. Following the paperwork, participants practiced maximal voluntary contractions (MVCs), the experimental upper extremity (UE) protocol, and the experimental lower extremity (LE) protocol. Within 48-72 hours following the familiarization day, participants returned to the laboratory for the experimental trial (day 2).

2.4. Isometric Maximal Voluntary Contractions (MVCs)

Maximal isometric strength testing was performed on the right arm and leg using a Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA). All the participants were seated with restraining straps over the trunk, pelvis, and thigh, and the input axis of the dynamometer was aligned with the axis of rotation of the elbow and knee (Beck, Kasishke, Stock, & DeFreitas, 2012; Conchola et al., 2013; Stock, Beck, DeFreitas, & Ye, 2013; Thompson et al., 2011). All isometric torque assessments for the EE and EF were performed with a shoulder angle of 90º in the sagittal plane with an elbow angle of 90º between the arm and forearm (Beck et al., 2005; Beck et al., 2012; Bilodeau et al., 2001). All isometric torque assessments for the KE and KF were performed at knee angles of 120º and 150º, respectively (Conchola et al., 2013). Prior to maximal isometric strength testing, the participants performed a 5-minute warm-up on the upper body ergometer (Cybex International, Inc., Medway, MA, USA) or cycle ergometer (Monark Exercise 828E, Vansbro, Sweden) at a self-selected low-intensity workload, for either the upper or lower extremities respectively. In addition to the 5-minute warm-up, 3 submaximal isokinetic muscle actions were performed at $60^{\circ}\cdot s^{-1}$ at approximately 75% of their perceived maximal effort for each muscle group. Following the sub-maximal contractions, each participant performed 2-3 isometric MVCs with the EF/EE or KF/KE with 1 minute of recovery between each contraction. The order of testing was randomized, with a 20 minute rest period between upper and lower extremity experimental protocols, to control for any potential effects of fatigue or influence of testing order. The participants were verbally instructed to ‘pull’ or ‘push,’ “as hard and fast as possible” for a total of 3–4 seconds for all MVCs (Thompson, Ryan, Sobolewski, Conchola, & Cramer, 2013). This process was repeated immediately following each of the experimental protocols for both the upper and lower extremity.

2.5. Isokinetic MVCs

Maximal isokinetic velocity (Vmax) testing was performed on the right arm and leg at a velocity of 500 $^{\circ}\cdot s^{-1}$ using a Biodex System 3 isokinetic dynamometer (Biodex

Medical Systems, Inc., Shirley, NY, USA). All the participants were seated with restraining straps over the trunk, pelvis, and thigh, and the input axis of the dynamometer was aligned with the axis of rotation of the elbow and knee. All isokinetic assessments for the EE were positioned with an elbow angle of 90º between the arm and forearm and EF at ~180º (or fully extended), and was performed with a shoulder angle of 90º in the sagittal plane through ~90º range of motion (ROM), using a neutral handgrip (Beck et al., 2005; Beck et al., 2012; Bilodeau et al., 2001). All isokinetic assessments for the KE started at a knee angle of 90º and KF were positioned at a knee angle of ~180º (or fully extended), and will be performed through ~90º ROM. Each participant performed 2-3 isokinetic MVCs with the EF/EE or KF/KE with 1 minute of recovery between each contraction. Vmax was used to assess the maximal shortening velocity of the muscle-limb unit where there was no resistance (with the exception of the lever arm) provided throughout the duration of the contraction (i.e. velocity of the dynamometer was set above all subjects' maximum velocity capacities), in accordance with the procedures of Thompson et al. (2014). The order of testing was randomized, with a 20 minute rest period between upper and lower extremity experimental protocols, to control for any potential effects of fatigue or influence of testing order. The participants were verbally instructed to 'pull' or 'push,' "as hard and fast as possible". This process was repeated immediately following each of the experimental protocols for both the upper and lower extremity (Aagaard et al., 2000; Thompson et al., 2011).

2.6. Experimental Upper Extremity (UE) Protocol

Five minutes following the Pre MVCs, participants performed the UE protocol consisting of 50 repetitions of dynamic isokinetic contractions at $180^{\circ}\cdot s^{-1}$ (medium velocity) for the upper extremity (EE/EF) (Beck et al., 2005). Participants were seated and strapped into the Biodex dynamometer identically to the MVC procedures. A neutral handgrip, with the elbow secured to the arm pad (using a flexible velcro band/strap), was used in order to perform both elbow extension and flexion throughout the protocol. This was performed with a shoulder angle of 90º in the sagittal plane, through ~90º ROM. During the protocol, participants were asked to provide maximal effort and verbally instructed to ‘pull’ or ‘push,’ as hard as they can throughout the entire 50 repetitions. Immediately after the protocol the Post MVCs were performed.

2.7. Experimental Lower Extremity (LE) Protocol

Five minutes following the Pre MVCs, participants performed the LE protocol consisting of 50 repetitions of dynamic isokinetic contractions at $180^{\circ}\cdot s^{-1}$ (medium velocity) for the lower extremity (KE/KF). Participants were seated and strapped into the Biodex dynamometer identically to the MVC procedures. Additionally, participants started the protocol with their knee angle at 90º, and their leg strapped to the Biodex lever arm just above the ankle. The lower extremity protocol was performed through ~90º ROM. During the protocol, participants were asked to provide maximal effort and verbally instructed to ‘pull’ or ‘push,’ as hard as they can throughout the entire 50 repetitions. Immediately after the protocol the Post MVCs were performed.

2.8. Signal Processing

The torque (N·m) and velocity ($deg\cdot s^{-1}$) signals were sampled simultaneously at 2 kHz with a Biopac data acquisition system (MP100WSW, Biopac Systems, Inc.; Santa Barbara, CA, USA), stored on a personal computer (Dell Inspiron 8200, Dell Inc., Round

Rock, TX, USA), and processed off-line with custom-written software (LabVIEW 8.5, National Instruments, Austin, TX, USA). The torque signal was smoothed using a 25ms moving average. All subsequent analyses were performed on the scaled and filtered torque signal. Isometric MVC PT was determined as the highest 25ms epoch during the entire 3–4 s MVC plateau (Conchola et al., 2013; Thompson et al., 2013). Vmax ($deg \cdot s^{-1}$) was calculated as the highest velocity attained during the unloaded MVC. ACC ($deg \cdot s^{-2}$) was determined as the 10ms that demonstrated the highest linear slope of the velocity-time curve (Δvelocity/Δtime). These procedures were used to obtain the linear portion of the rate of rise in velocity, while excluding the deceleration or "rounding off" of the signal observed at the edge of the velocity plateau. The onset of velocity was determined as the point when the velocity signal reached a threshold 2 $deg \cdot s^{-1}$ above baseline. The MVC with the highest Vmax or ACC was used for all analyses (Thompson et al., 2014). The highest values for ACC, PT, and Vmax from the Pre and Post MVCs were used to calculate FI using the following equation: ([Post – Pre]/Pre) × 100 (Beck et al., 2012).

2.9. Statistical Analysis

Separate 2-way mixed factorial ANOVAs [group (TRT vs. ERT) × time (Pre vs. Post)] were performed for each dependent variable (PT, Vmax, and ACC) for each muscle group, as well as [group (TRT vs ERT) × muscle (KE,KF,EE,EF)] for fatigue index. PASW software version 21.0 (SPSS Inc, Chicago, IL, USA) was used for all statistical analyses. An alpha level of $p \leq 0.05$ was considered significant for all comparisons. One-way ANOVAs and t-tests were utilized as necessary to decompose any significant interactions.

CHAPTER III

RESULTS

3.1. Acceleration (ACC)

Means and *SD* for all ACC values are presented in Table 1. There were no significant group × time interactions ($F_{1,18}$ = 0.0001-2.263, p = 0.150-0.996) for all muscle groups (KE, KF, EF, or EE); nor any main effects for group ($p \geq 0.05$). However, significant main effects for time ($F_{1,18}$ =13.373-94.529, $p \leq 0.002$) were observed in which ACC was greater at Pre compared to Post (p = 0.0001-0.002) for all muscle groups. Additionally, for FI, no significant group × muscle interaction ($F_{3,54}$ = 1.299, p = 0.284); nor main effect for group ($p \geq 0.05$) was observed for ACC. There was, however, a significant main effect for muscle ($F_{3,54}$ = 9.257, p = 0.0001), in which the deficit (-28.02 ± 10.90%) in ACC of the EF was greater compared to all other muscles (p = 0.001-0.016). No significant differences were observed between all other muscle groups ($p \geq$ 0.05).

Table 1. Mean ± *SD* values for acceleration (ACC) between Traditional (TRT, n = 12) and Explosive (ERT, n = 8) resistance trained individuals for both time phases (Pre & Post) and fatigue index (FI) of each muscle group. *Marginal mean collapsed across groups.

Muscle	Group	Pre ($deg{\cdot}s^{-2}$)	Post ($deg{\cdot}s^{-2}$)	FI(%)
	TRT	4065.67 ± 747.69	3666.38 ± 427.89	-7.10 ± 20.65
KE	ERT	4166.61 ± 469.51	3494.62 ± 423.37	-15.74 ± 9.50
	Mean *	4106.05 ± 638.31	3597.68 ± 423.66^{F}	-10.56 ± 17.29^{B}
	TRT	3352.98 ± 560.41	3053.20 ± 486.62	-7.83 ± 15.73
KF	ERT	3562.77 ± 463.59	2967.00 ± 348.51	-16.28 ± 7.54
	Mean *	3436.90 ± 521.65	3018.72 ± 428.62^{F}	-11.21 ± 13.50^{B}
	TRT	2633.69 ± 316.69	2176.58 ± 281.22	-16.42 ± 13.04
EE	ERT	2462.02 ± 321.71	2123.28 ± 284.70	-13.28 ± 9.50
	Mean *	2565.02 ± 321.93	2155.26 ± 276.34^{F}	-15.16 ± 11.59^{B}
	TRT	2229.13 ± 282.22	1598.41 ± 280.83	-27.73 ± 12.22
EF	ERT	2177.69 ± 333.61	1546.25 ± 249.39	-28.46 ± 9.34
	Mean *	2208.56 ± 296.28	1577.55 ± 263.17^{F}	-28.02 ± 10.90^{Q,H,T}

F = significantly different (p < 0.05) across time from the fatigue protocol
Q = significantly different (p < 0.05) from the knee extensors
H = significantly different (p < 0.05) from the knee flexors
T = significantly different (p < 0.05) from the elbow extensors
B = significantly different (p < 0.05) from the elbow flexors

3.2. Peak Torque (PT)

Means and *SD* for all PT values are presented in Table 2. There were no significant group × time interactions ($F_{1,18}$ = 0.661-2.542, p = 0.128-0.427) for all muscle groups (KE, KF, EF, or EE). However, when collapsed across time, a main effect for group ($F_{1,18}$ =5.575, p = 0.030) was observed only for the EF. Additionally, significant main effects for time ($F_{1,18}$ = 15.294-37.328, $p \leq$ 0.001) were observed in which PT was greater at Pre compared to Post (p = 0.0001-0.001) for all muscle groups (KF, EF, or EE), with the exception of the KE ($F_{1,18}$ = 3.859, p = 0.065). Furthermore, for FI, no significant group × muscle interaction ($F_{3,54}$ = 2.232, p = 0.095); nor a main effect for group ($p \geq$ 0.05) for peak torque was observed. There was, however, a significant main effect for muscle ($F_{3,54}$ = 4.725, p = 0.005), in which the deficit in PT of the EF was greater (p = 0.022) compared to the KE muscle group (i.e., -19.56 ± 10.96% vs. -6.11 ± 15.16%). No significant differences were observed between all other muscle groups ($p \geq$ 0.05).

Table 2. Mean ± *SD* values for peak torque (PT) between Traditional (TRT, n = 12) and Explosive (ERT, n = 8) resistance trained individuals for both time phases (Pre & Post) and fatigue index (FI) of each muscle group. *Marginal mean collapsed across groups.

Muscle	Group	Pre (N·m)	Post (N·m)	FI (%)
KE	TRT	252.35 ± 56.69	227.90 ± 45.46	-8.67 ± 14.18
	ERT	220.72 ± 52.61	210.59 ± 33.88	-2.26 ± 16.74
	*Mean**	239.70 ± 55.97	220.98 ± 41.17	-6.11 ± 15.16^{B}
KF	TRT	136.75 ± 28.47	123.30 ± 22.02	-9.09 ± 12.08
	ERT	132.13 ± 19.08	106.74 ± 15.13	-18.90 ± 7.13
	*Mean**	134.90 ± 24.67	116.68 ± 20.84^{F}	-13.01 ± 11.29
EE	TRT	75.34 ± 11.35	60.33 ± 8.52	-18.52 ± 14.20
	ERT	67.94 ± 10.75	60.42 ± 17.28	-11.82 ± 15.38
	*Mean**	72.38 ± 11.45	60.36 ± 12.33^{F}	-15.84 ± 14.67
EF	TRT	92.78 ± 11.89	72.18 ± 9.63	-21.36 ± 11.48
	ERT	81.48 ± 8.79	67.23 ± 6.93	-16.86 ± 10.27
	*Mean**	88.26 ± 11.94	70.20 ± 8.81^{F}	-19.56 ± 10.96^{Q}

F = significantly different (p < 0.05) across time from the fatigue protocol
Q = significantly different (p < 0.05) from the knee extensors
B = significantly different (p < 0.05) from the elbow flexors

3.3. Peak Velocity (Vmax)

Means and *SD* for all Vmax values are presented in Table 3. There were no significant group × time interactions ($F_{1,18}$ = 0.015-1.800, p = 0.196-0.903) for all muscle groups (KE, KF, EF, or EE); nor any main effects for group ($p \geq 0.05$). However, significant main effects for time ($F_{1,18}$ = 14.898-68.687, $p \leq 0.001$) were observed in which Vmax was greater at Pre compared to Post (p = 0.0001-0.001) for all muscle groups. Additionally, for FI, no significant group × muscle interaction ($F_{3,54}$=0.734, p = 0.536); nor a main effect for group ($p \geq 0.05$) was observed for Vmax. There was, however, a significant main effect for muscle ($F_{3,54}$=20.904, p = 0.0001), in which the deficit (-16.07 ± 7.43%) in Vmax of the EF was greater compared to all other muscles ($p \leq 0.001$). No significant differences were observed between all other muscle groups ($p \geq 0.05$).

Table 3. Mean ± *SD* values for peak velocity (Vmax) between Traditional (TRT, n = 12) and Explosive (ERT, n = 8) resistance trained individuals for both time phases (Pre & Post) and fatigue index (FI) of each muscle group. *Marginal mean collapsed across groups.

Muscle	Group	Pre (deg·s^{-1})	Post (deg·s^{-1})	FI (%)
KE	TRT	469.05 ± 34.07	450.46 ± 27.89	-3.70 ± 6.42
	ERT	478.83 ± 16.45	448.89 ± 32.74	-6.31 ± 4.94
	*Mean**	472.96 ± 28.21	449.83 ± 29.08^{F}	-4.74 ± 5.88^{B}
KF	TRT	477.77 ± 17.73	466.45 ± 26.64	-2.36 ± 4.57
	ERT	485.97 ± 16.79	463.42 ± 21.62	-4.65 ± 2.53
	*Mean**	481.05 ± 17.40	465.24 ± 24.20^{F}	-3.28 ± 3.97^{B}
EE	TRT	417.33 ± 22.66	386.11 ± 23.02	-7.26 ± 6.81
	ERT	393.73 ± 27.74	372.99 ± 31.01	-5.15 ± 6.58
	*Mean**	407.89 ± 26.86	380.86 ± 26.55^{F}	-6.41 ± 6.62^{B}
EF	TRT	427.84 ± 26.95	359.44 ± 25.98	-15.65 ± 8.24
	ERT	416.70 ± 39.31	346.22 ± 33.85	-16.69 ± 6.49
	*Mean**	423.39 ± 31.96	354.15 ± 29.28^{F}	-16.07 ± 7.43^{Q,H,T}

F = significantly different (p < 0.05) across time from the fatigue protocol
Q = significantly different (p < 0.05) from the knee extensors
H = significantly different (p < 0.05) from the knee flexors
T = significantly different (p < 0.05) from the elbow extensors
B = significantly different (p < 0.05) from the elbow flexors

CHAPTER IV

DISCUSSION

The purpose of this study was to examine the effects of fatigue on strength and rapid force characteristics of the UE and LE with TRT and ERT males after performing a dynamic fatigue protocol. It was hypothesized that; (1) the TRT group would produce a higher PT than the ERT group, (2) the ERT group would have a faster ACC and produce a higher Vmax than the TRT group, (3) the TRT group would retain higher strength measures after the protocol, and (4) the ERT group would retain higher rapid measures after the protocol. In contrast to these hypotheses, the key findings of present investigation revealed that no significant differences were observed between TRT and ERT males, following a fatigue-inducing bout of repetitive isokinetic contractions of the upper and lower extremities. Although no differences were observed between the groups for all variables (i.e., PT, Vmax, ACC, and FI), when collapsed across groups, PT, Vmax, and ACC were significantly lower immediately following the dynamic isokinetic protocol for all muscle groups, with the exception of the KE for PT. Specifically, the EF were fatigued to a greater extent than the KE, KF, and EE for Vmax and ACC, and to the KE for PT, respectively.

Findings of decreased maximal isometric torque following a bout of dynamic isokinetic exercise is similar to those of previous studies, which have reported significant decreases in maximal isometric torque for the KE (Stock, Beck, & DeFreitas, 2011; Stock et al., 2013; Thorstensson & Karlsson, 1976), and EF (Clarkson et al., 1982; Linnamo et al., 2000; Yoon, Schlinder-Delap, & Hunter, 2013), after performing isokinetic contractions involving knee extensions or elbow flexions, respectively. Additionally, the decrease of ACC in the EF immediately following the protocol is similar to the findings of Nguyen et al. (2009), who reported a significant decrease in EF ACC immediately following a dynamic isokinetic eccentric protocol. Thus, taken together these findings suggest that both strength and rapid force capacities are significantly reduced immediately following a bout of repeated dynamic isokinetic contractions and that different types of resistance-trained individuals may respond similarly. These deficits may be due to the effects of peripheral fatigue as a consequence of high-intensity muscular contractions from the dynamic isokinetic protocols. Fatigue is a complex process that may involve both metabolic and neural physiological changes. Mechanisms of neuromuscular fatigue have largely been characterized as being peripheral, likely occurring from an inability to restore Na^+ and K^+ gradients across the sarcolemma resulting in large amounts of K^+ being depleted, thereby leading to impaired action potential conduction efficiency (Green, 1997). Additionally, metabolic by-product buildup from increases of inorganic phosphate, ADP, AMP, and H^+ could affect the ATPase activity and thus decrease the reuptake of Ca^{2+}. The decreased Ca^{2+} reuptake combined with an inhibition of the t-tubules which reduces sarcoplasmic reticulum calcium release may lead to decreased sensitivity at the cross-bridge binding sites (Fitts, 2006). Furthermore, it is possible that increases in acidity levels resulting from the numerous amount of maximal muscular contractions, such as in the present dynamic isokinetic protocols, may lead to reduced rates of glycogenolysis and creatine phosphate resynthesis (Tesch, Colliander, & Kaiser, 1986) as well as stimulation of group III and IV chemoreceptor afferent neurons which have inhibitory effects on the α-motoneurons innervating the fatigued muscle (Bigland-Ritchie, Dawson, Johansson, & Lippold, 1986). Taken together, these fatigue-related physiological alterations may be a contributing factor to the consequences on strength and rapid force characteristics following a fatigue-induced protocol due to prohibiting the optimization of muscle contraction and force regulation responses.

FI (or percent decline) has been reported in multiple studies (Stock et al., 2011; Stock et al., 2013), however, there seems to be a paucity of research that has looked at FI between different muscle groups, for multiple variables, following a similar fatigue inducing bout of exercise. As stated above, it seems the EF will fatigue to a greater extent after completing 50 dynamic isokinetic contractions, compared to the other muscles for ACC, Vmax, and PT. It should be noted that a reduction (11.24%) in grip strength was observed from Pre (54.70 ± 8.56) to Post (48.55 ± 7.90). Despite the fact this wasn't part of the primary investigation, this is of interest because it may have affected results of the EF. A possible reason for this could be due to having to assist the EF to a greater extent during the UE protocol, however, this is speculation and further research will need to be conducted to elucidate the actual role this played during a protocol utilizing a neutral grip for repeated isokinetic muscle actions.

Not unlike other studies, this one has its limitations. The sample and unequal number of participants in each group is a limitation that cannot be overlooked. This may have been one reason no differences were observed between groups. Additionally, participants were put into separate resistance-trained groups based on self-reporting on the health history questionnaire and listing exercises they do regularly. This is a limitation because although there were obvious differences in workout regiments, it was impossible to negate any overlap in types of resistance-training exercises. Had the groups been mutually exclusive differences may have been observed. Furthermore, another limitation was the training status of the groups. Each group, on average, had been resistance-training for 3-4 years which could lead to some similar responses to training adaptations. Although the upper and lower extremity protocols were randomized and had a 20 minute rest between them, a possible limitation is that they were held on the same day instead of two separate days. There is a chance, if the rest period wasn't long enough, that individuals were not fully recovered when it came time to start the next protocol.

Due to the findings of this study, more research will need to be performed to find acquired training-specific differences between TRT and ERT groups and muscle groups. Future studies should involve the use of EMG to look at possible differences in agonist and antagonist activation during isometric and dynamic isokinetic contractions between resistance-trained groups. Additionally, future studies should look into using a variety of functional measures in combination of isometric and isokinetic assessments to see if other differences would be observed.

This study involved looking at two different resistance-trained groups (TRT & ERT), four muscle groups (KE, KF, EE, EF), four main variables (ACC, PT, Vmax, &

FI), and two time points (Pre & Post). Although no significant findings were observed between groups, there were significant differences found from the Pre to Post time points for all muscle groups and all variables, with the exception of KE PT. Interestingly, the FI of the EF was considerably higher compared to that of the other muscle groups, despite having gone through the exact protocol. The evidence from the present study seems to support the idea that resistance-trained individuals may react similarly when put through a fatiguing bout of dynamic isokinetic exercise. However, it has been shown that the adaptations to training may be specific to the modality of the training (Jones & Rutherford, 1987). Therefore, it is possible that training specificity of the two groups (i.e., TRT and ERT) led to adaptations that may not completely transfer to isokinetic and isomeric performance assessments since they are different modalities.

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APPENDICES

A. THESIS OVERVIEW

1. Statement of Purpose

The purpose of this study was to examine the effects of fatigue on strength and rapid force characteristics between TRT and ERT males after performing a dynamic fatigue protocol.

2. Research Questions

2.1. Do adaptations to TRT produce greater maximal torque compared to ERT?

2.2. Is acceleration and peak velocity dependent on modes of resistance training?

2.3. Will adaptations to different resistant training modes affect the fatigability of skeletal muscle?

2.4. Will TRT individuals retain higher strength measures after the protocol?

2.5. Will ERT individuals retain higher rapid measures after the protocol?

3. Hypotheses

3.1. The TRT group would produce a higher PT than the ERT group.

3.2. The ERT group would have a faster ACC and produce a higher Vmax than the TRT group.

3.3. The TRT group would retain higher strength measures after the protocol.

3.4. The ERT group would retain higher rapid measures after the protocol.

4. Assumptions

4.1. The population from which the sample is drawn is normally distributed.

4.2. All participants accurately answered the health history questionnaire.

4.3. All participants provided maximal exertion for the protocols.

4.4. Equipment functions properly for all testing sessions.

4.5. No data collection, data entry, data analysis, or statistical processing errors.

5. Limitations

5.1. Sample size.

5.2. Subjects are resistance trained males (18-35 yrs)

5.3. Handheld goniometer was used to measure the arm and leg angle for all MVCs.

5.4. Differences in motivation levels between participants may produce varying levels of maximal exertion and effort for all assessments.

B. DEFINITION OF TERMS

Acceleration (ACC): also referred to as rate of velocity development. Rate of change in velocity.

Concentric Muscle Action: a muscle action in which the muscle shortens because the contractile force is greater than the resistive force.

Fatigue: any reduction in physical or mental performance, or any exercise-induced decrease in maximal voluntary force or power produced by a muscle or muscle group.

Fatigue Index (FI): also referred to as percent decline. Used for measuring ability to resist fatigue using this equation [(Post – Pre)/Pre x 100].

Hypertrophy: muscle enlargement resulting from training, primarily owing to an increase in the cross-sectional area of the existing fibers.

Isokinetic Strength Testing: maximal tension is developed at all joint angles throughout the range of motion. Speed, or Velocity, is constant because there is accommodating resistance at a controlled speed of movement.

Isometric Muscle Action: a muscle action in which the muscle length does not change because the contractile force is equal to the resistive force.

Maximal Voluntary Contraction (MVC): participant attempts to concentrically contract as hard as possible with the limb in a fixed position.

Power Training: lifting light-to-moderate loads at high velocities.

Specificity Principle: also referred to as the specific adaptation to imposed demands (SAID) principle. This states that the training is most effective when the resistance exercises are similar to the sport or activity in which improvement is sought.

Strength: the maximal force that a muscle or muscle group can generate at a specified velocity.

Strength Training: heavy resistance training with slow velocities.

Torque: application of force to an object on an axis.

Velocity: the rate of motion in a specific direction.

C. REVIEW OF LITERATURE

Aagaard, P., et al., Antagonist muscle coactivation during isokinetic knee extension.

The aim of this study was to quantify the amount of antagonist coactivation and the resultant moment of force generated by the hamstring muscles during maximal quadriceps contraction while performing slow isokinetic knee extension. The net joint moment at the knee joint and electromyography (EMG) signals were measured from the following muscles (vastus medialis, vastus lateralis, rectus femoris muscles and the biceps femoris caput longum and semitendinosus) in male subjects during maximal isokinetic knee extension. Two types of extension were performed: (1) maximal concentric quadriceps contractions and (2) maximal eccentric hamstring contractions. Hamstring antagonist EMG in (1) were converted into antagonist moment based on the EMG-moment relationships determined in (2) and vice versa. Antagonist muscle coactivation was present in both (1) and (2). Substantial hamstring coactivation was observed during quadriceps agonist contraction. This resulted in a constant level of antagonist hamstring moment of about 30 N·m throughout the range of motion. The authors concluded that substantial antagonist coactivation of the hamstring muscles may be present during slow isokinetic knee extension. Additionally, substantial antagonist flexor moments are generated. The antagonist hamstring moments potentially counteract the anterior tibial shear and excessive internal tibial rotation induced by the contractile forces of the quadriceps near full knee extension. In doing so the hamstring coactivation is suggested to assist the mechanical and neurosensory functions of the anterior cruciate ligament.

Abernethy, P. J., et al., Acute and chronic response of skeletal muscle to resistance exercise.

Skeletal muscle tissue is sensitive to the acute and chronic stresses associated with resistance training. These responses are influenced by the structure of resistance activity (i.e. frequency, load and recovery) as well as the training history of the individuals involved. Increases in cross-sectional area of muscle after resistance training can be primarily attributed to fiber hypertrophy. However, there may be an upper limit to this hypertrophy. Furthermore, significant fiber hypertrophy appears to follow the sequence of fast twitch fiber hypertrophy preceding slow twitch fiber hypertrophy. The purpose of this article was to summarize some of the skeletal muscle responses to acute and chronic resistance activity.

Beck, T. W., et al., Comparison of Fourier and wavelet transform procedures for examining the mechanomyographic and electromyographic frequency domain responses during fatiguing isokinetic muscle actions of the biceps brachii.

The primary purpose of this study was to compare the fast Fourier transform with the discrete wavelet transform for determining the mechanomyographic and electromyographic center frequency (mean power frequency, median frequency, or wavelet center frequency) patterns during fatiguing isokinetic muscle actions of the biceps brachii. Subjects volunteered to perform 50 consecutive maximal, concentric isokinetic muscle actions of the dominant forearm flexors at a velocity of 180° s^{-1} through a 90° range of motion using a neutral handgrip. This study was included primarily because of the authors fatigue protocol and isokinetic testing setup.

Beck, T. W., et al., Neural Contributions to Concentric vs. Eccentric Exercise–Induced Strength Loss.

The purpose of this study was to examine the strength, EMG, and mechanomyographic (MMG) responses after workouts designed to elicit fatigue and muscle damage vs. only fatigue. Subjects performed 6 sets of 10 maximal concentric isokinetic or eccentric isokinetic muscle actions of the dominant forearm flexors on 2 separate days. Before (Pre) and after (Post) these workouts, peak torque , surface EMG, and MMG signals were measured during maximal concentric isokinetic, eccentric isokinetic, and isometric muscle actions of the forearm flexors. The results indicated 26 and 25% decreases in PT after concentric and eccentric exercises, respectively.This study was included for the information pertaining to the use of the author's isometric strength testing and signal processing.

Behm, D. G., Neuromuscular implications and applications of resistance training.

Strength gains have been attributed to neural adaptations such as alterations in recruitment, rate coding, synchronization of motor units, reflex potentiation, co-contraction of antagonists, and synergistic muscle activity. Although most training studies show increases in EMG, a few have shown increase in strength with no apparent changes in neural drive. This may highlight the importance of motor control and the reorganization of supraspinal inputs. High intensity concentric and eccentric contractions with arousal and imagery techniques merit further study in promoting optimal neural adaptations. Most velocity specificity studies have emphasized movement rather than contraction speed, which may be the predominant factor. The high rate of force development achieved with explosive contractions should serve as a template for power training. The extent of muscle hypertrophy is dependent upon protein degradation and synthesis, which may be enhanced through high intensity, high volume eccentric and concentric contractions.

Bilodeau, M., et al., Fatigue of elbow flexor muscles in younger and older adults.

The aim of this study was to assess differences in fatigue-related responses of neuromuscular function between younger and older healthy adults. Measures reflecting changes in voluntary activation, neuromuscular propagation, metabolite build-up, and excitation-contraction coupling processes were taken before, during, and after a sustained maximum elbow-flexion fatigue task which consisted of maintaining a maximum elbow flexion effort until the torque dropped below 50% of the participants maximal voluntary contraction (MVC). The authors found a greater role for failure in voluntary activation (central fatigue) in about half of the older subjects compared with zero of the younger subjects to explain the decrease in force-generating capacity with sustained activity. In contrast, similar behaviors in measures reflecting changes in peripheral mechanisms were noted for the two age groups. The results point to a potential shift in fatigue mechanisms with age, such as central fatigue seems to be affected greater for older male adults compared to younger males.

Campos, G. E., et al., Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones.

Subjects in this study participated in an 8-week progressive resistance-training program to investigate the "strength–endurance continuum". Subjects were divided into four groups: a low repetition group (Low Rep) performing 3–5 repetitions maximum (RM) for four sets of each exercise with 3 min rest between sets and exercises, an intermediate repetition group (Int Rep) performing 9–11 RM for three sets with 2 min rest, a high repetition group (High Rep) performing 20–28 RM for two sets with 1 min rest, and a non-exercising control group (Con). Three exercises (leg press, squat, and knee extension) were performed 2 days/week for the first 4 weeks and 3 days/week for the final 4 weeks. Maximal strength and local muscular endurance were assessed at the beginning and end of the study. Maximal strength improved significantly more for the Low Rep group compared to the other training groups, and the maximal number of repetitions at 60% 1RM improved the most for the High Rep group. In addition, time to exhaustion significantly increased at the end of the study for only the High Rep group. All three major fiber types (types I, IIA, and IIB) hypertrophied for the Low Rep and Int Rep groups, whereas no significant increases were demonstrated for either the High Rep or Con groups. All three training regimens resulted in similar fiber-type transformations (IIB to IIA), the low to intermediate repetition resistance-training programs induced a greater hypertrophic effect compared to the high repetition regimen. The High Rep group appeared better adapted for submaximal, prolonged contractions, with significant increases in time to exhaustion. The present findings suggest that intensity and number of repetitions performed may dictate the physical and physiological adaptations that occur.

Caserotti, P., et al., Explosive heavy-resistance training in old and very old adults: changes in rapid muscle force, strength and power.

This study investigated the effects of 12 weeks of explosive-type heavy-resistance training (75–80% of 1RM) protocol in old and very old women. Training was performed with maximal intentional acceleration of the training load during the concentric movement phase. MVC, rate of force development (RFD), impulse, and maximal muscle power were measured during a countermovement jump (CMJ) and during unilateral leg extension task (LEP). RFD, impulse, MVC, CMJ, and LEP increased in both groups. The authors findings revealed that explosive-type heavy-resistance training seems to be safe and well tolerated in healthy elderly women. Specifically, adaptive neuromuscular changes in selected physiological variables that are commonly associated with the risk of falls and disability in aged individuals.

Channell, B. T. and Barfield, J., Effect of Olympic and traditional resistance training on vertical jump improvement in high school boys.

The purpose of this study was to compare the effects of a ballistic resistance training program of Olympic lifts with those of a traditional resistance training program of power lifts on vertical jump improvement in male high school athletes. There was no significant mean difference among Olympic trained, power trained, and control groups, but large effect sizes between Olympic trained versus control and power trained versus control. This study suggests that both Olympic and power training are effective in improving vertical jump performance in male high school athletes. Findings from the study indicated that Olympic lifts as well as power lifts provide improvement in vertical jump performance and that Olympic lifts may provide a modest advantage over power lifts for vertical jump improvement in high school athletes.

Conchola, E., et al., Effects of neuromuscular fatigue on the electromechanical delay of the leg extensors and flexors in young and old men.

The purpose of this study was to investigate the effects of a fatigue-inducing bout of submaximal, intermittent isometric contractions on the electromechanical delay (EMD) of the leg extensors and flexors in young and old men. Subjects performed MVCs followed by a fatigue-inducing protocol consisting of intermittent isometric contractions of the leg extensors or flexors using a 0.6 duty cycle (6 s contraction, 4 s relaxation) at 60 % of MVC until volitional fatigue. MVCs were again performed at 0, 7, 15, and 30 min post fatigue. The authors found differential fatigue-induced EMD recovery patterns between the leg extensors and flexors with the flexors being slower to recover and also that age-related increases of EMD are muscle group specific.

Fielding, R. A., et al., High-velocity resistance training increases skeletal muscle peak power in older women.

The purpose of this study was to see if a high-velocity resistance-training program would increase muscle power more than a traditional (TRT) resistance-training program. The authors used thirty women as their participants and randomly placed them into either a high-velocity or TRT group that trained for 16 weeks. Training was conducted three times per week and comprised of leg press and knee extension exercises. Results showed that muscle strength increased similarly in both groups but the high-velocity group was able to generate higher power than the TRT group.

Gandevia, S. C., Some central and peripheral factors affecting human motoneuronal output in neuromuscular fatigue.

Fatigue may be defined as a reduction in the maximal force-generating capacity of a muscle. It may result from peripheral processes distal to the neuromuscular junction and from central processes controlling the discharge rate of motoneurons. When assessed with a sensitive test using twitch interpolation, most MVCs approach but do not attain optimal muscle output. During fatigue, reflex inputs from intramuscular receptors may contribute to a decline in motor unit discharge rate or a decline which optimizes force production during maximal efforts.

Hakkinen, K., and Keskinen, K. L., Muscle cross-sectional area and voluntary force production characteristics in elite strength- and endurance-trained athletes and sprinters.

Male elite strength-trained athletes (SA), elite sprinters (SPA) and elite endurance-trained athletes (EA) volunteered for examination of their muscle cross-sectional area (CSA) using an ultrasonic apparatus, maximal voluntary isometric force using a dynamometer, force-time and relaxation-time characteristics of the KE muscles. The SA group demonstrated slightly greater CSA and maximal absolute strength than the SPA group, while the EA group demonstrated the smallest values both in CSA and especially in maximal strength .When the maximal forces were related to CSA of the muscles, the mean value for the SA group of remained slightly greater than that recorded in the SPA group and significantly greater than that recorded in the EA group. The mean value in the SPA was also significantly greater than that of the EA group. The isometric force-time curves differed between the groups so that the times taken to produce the same absolute force were the shortest in the SPA group and the longest in the EA group. With force expressed as a percentage of the maximum, the force-time curves showed that the SPA group demonstrated still shorter times to a given value, especially at the lower force levels, than the other two groups. With regard to the differences in force production the rate and amount of neural activation of the muscles and/or in the qualitative characteristics of the muscle tissue itself. The results characterize the very specific nature of high resistance strength-, sprint- and endurance-training over a prolonged period of time.

Hooper, D. R., et al., Effects of resistance training fatigue on joint biomechanics.

Resistance training has been found to have a multitude of benefits. However, when performed with short rest, resistance training can result in substantial fatigue, which may have a negative impact on exercise technique. The purpose of this study was to examine the effects of fatigue from resistance exercise on joint biomechanics to determine what residual movement effects may exist after the workout. Twelve men with at least 6 months of resistance training experience performed 5 body weight squats before and after (Pre,Post) a highly fatiguing resistance training workout, which consisted of 10 sets at 75% of 1RM for the back squat, bench press, and deadlift. Peak angle, total displacement, and rate of movement were assessed for knee flexion, trunk flexion, hip flexion, hip rotation, and hip adduction. Upon completion of the fatigue protocol, it was found that a significant decrease in peak angle was observed for knee flexion, hip flexion, and hip adduction. Further, there was a significant reduction in angular displacement for knee flexion, hip flexion, hip adduction, and hip rotation. Lastly, a significant reduction in displacement rate for knee flexion, hip flexion, hip adduction, and hip rotation were also observed. This study demonstrated that there are acute effects on movement capabilities after a high-intensity short rest protocol.

Izquierdo, M., Neuromuscular fatigue after resistance training.

This study examined the effects of heavy resistance training on dynamic exercise-induced fatigue tasks after two loading protocols with the same relative intensity and absolute load in pre-training in men .Maximal strength, muscle power, surface EMG was measured before and after exercise. After training, when the relative intensity of the fatiguing dynamic protocol was kept the same, the magnitude of exercise-induced loss in maximal strength was greater than that observed before training. The peak power lost after was greater than the corresponding exercise-induced decline observed in isometric strength. However, after training the muscle is relatively able to work more before task failure. The results of this study may indicate that rate of fatigue development (i.e. power and MVC) was faster and more profound after training despite using the same relative intensity.

Jozsi, A. C., et al., Changes in power with resistance training in older and younger men and women.

It is suggested that muscle power diminishes with increasing age and inactivity. However, the capacity for older adults to increase muscle power with resistance exercise has not been fully examined. For the present study, the authors examined the influence of progressive resistance training on muscle power output in young and old males and females. All subjects performed 12 weeks of the training at a workload equivalent to 80% of the one repetition maximum (1RM). Participants performed five exercises, three sets per exercise, twice weekly. Muscle power was measured at resistances equivalent to 40, 60, and 80% of the 1RM, on the knee extension and arm pull machines (i.e., lat pulldowns and seated rows). All subjects increased arm pull power similarly at 40 and 60% of 1RM, independent of age or sex. There was not a significant increase in arm pull power at 80% of 1RM. Older and younger subjects also had similar absolute increases in leg extensor power at 40 and 60% of 1RM, but men responded with greater absolute gains than women at these percentages. The increase in leg extensor power at 80% of 1RM was similar in all groups. Older and younger subjects increased strength similarly in all exercises except the left knee extension. Independent of age, men increased strength more than women in all exercises except the double leg press. The results found by the authors may demonstrate that older individuals can still improve muscle power (and strength); however, men may realize greater absolute gains than women.

Judge, L. W., et al., Neural adaptations with sport-specific resistance training in highly skilled athletes.

The aim of this study was to assess the effects of variations in the volume and intensity of resistance training through a 16 week training program in highly skilled athletes on neural adaptive mechanisms. The pattern of neural drive was measured by analyzing isometric torque-time curves and EMG characteristics during the performance of rapid isometric contractions at maximal effort. The volume and intensity of training were varied at 4-weekly intervals to systematically emphasize the development of strength, power and motor performance in 14 highly skilled track and field athletes. KE strength increased significantly by 15% during steady maximal isometric contractions and by 24% during rapid isometric contractions at maximal effort after the 16-week training program. Increases in EMG amplitude and rate of EMG activation indicated that improvements to the pattern of neural drive occurred with sport-specific resistance training. The maximal and pattern of neural drive did not change in the control group.

Lattier, G., et al., Neuromuscular differences between endurance-trained, power-trained, and sedentary subjects.

This study tested the hypothesis that neuromuscular characteristics of plantar flexor (PF) and KE muscles explain differences of both performance in vertical jump and MVC between endurance-trained (END), power-trained (POW), and sedentary subjects (SED). Evoked twitch characteristics of PF and KE were measured. MVC, maximal voluntary activation (%VA) of KE, and performance in vertical jump were also measured. POW have higher maximal rate of twitch force development (MRFD) than SED and END for both PF and KE; %VA and MVC were higher for POW and END than SED. Higher performances were measured in vertical jump for POW compared with END and SED. Significant relationships were found between the squat jump performance and MRFD for both KE and PF. These findings show that low MRFD on lower limbs extensors does not limit expression of MVC on subjects with high levels of activation.

Mathiassen, S. E., Influence of angular velocity and movement frequency on development of fatigue in repeated isokinetic knee extensions.

For this study participants completed 15 tests, comprising 120s of repeated, maximal isokinetic knee extensions. The tests differed with respect to movement velocity ($30°\cdot s^{-1}$, $120°\cdot s^{-1}$, and $300°\cdot s^{-1}$), and movement frequency (5 at each velocity). At a given exercise time ratio, increasing movement velocity produced increasing fatigue. However, at a given muscular power output, fatigue developed to a greater extent at the low velocity than at the two higher ones, which did not differ significantly. Additionally, individual variation was seen in the positions of the low-, medium-, and high-velocity lines. These variations did not depend on the training background. The author claimed that this implies that the validity of using single-velocity, single-frequency tests in determining isokinetic endurance is doubtful, and further suggests incorporating multiple movement speeds for isokinetic testing for basic physiological research, and assessments of muscular performance.

McCaulley, G. O., et al., Acute hormonal and neuromuscular responses to hypertrophy, strength and power type resistance exercise.

The purpose of this study was to determine the acute neuroendocrine response to hypertrophy (H), strength (S), and power (P) type resistance exercise (RE) equated for total volume. Subjects completed three RE protocols and a rest day (R). The protocols included (1) H: 4 sets of 10 repetitions in the squat at 75% of 1RM (90 s rest periods); (2) S: 11 sets of three repetitions at 90% of 1RM (5 min rest periods); and (3) P: 8 sets of 6 repetitions of jump squats at 0% of 1RM (3 min rest periods). Peak force, RFD, and muscle activity from the vastus medialis (VM) and biceps femoris were determined during a maximal isometric squat test. The percent of baseline muscle activity of the VM immediately post was significantly greater following the H compared to the S protocol. It appears the H protocol elicits a unique pattern of muscle activity as well. RE protocols of varying intensity and rest periods elicit different acute neuroendocrine responses which indicate a unique physiological stimulus.

Murray, D. P., et al., Effects of velocity-specific training on rate of velocity development, peak torque, and performance.

The purpose of this investigation was to determine the effects of 4 weeks of slow ($60°\cdot s^{-1}$) vs. fast ($400°\cdot s^{-1}$) velocity training on rate of velocity development (RVD), PT, and performance. Twenty male students were tested, before and after 4 weeks of training, for PT production, RVD (at 60, 180, 300, 400, and $450°\cdot s^{-1}$), standing long jump distance, and 15- and 40-m sprint times. All participants underwent 8 training sessions, performing 5 sets of 5 repetitions of simultaneous, bilateral, concentric knee extension exercises on a Biodex System 3 isokinetic dynamometer at either 60° or $400°\cdot s^{-1}$. The results of these authors study support the suggestion that there is a significant neural adaptation to short-term isokinetic training performed by recreationally trained males, producing changes in limb acceleration and performance with little or no change in strength.

Newton, R. U., et al., Comparison of response to strenuous eccentric exercise of the elbow flexors between resistance-trained and untrained men.

This study compared resistance-trained and untrained men for changes in commonly used indirect markers of muscle damage after maximal voluntary eccentric exercise of the elbow flexors. The trained men were classified as one's who performed EF exercises at least three training sessions per week,, while the 15 untrained men did not perform any resistance training for at least 1 year. For the testing protocol, all subjects performed 10 sets of 6 maximal voluntary eccentric actions against the lever arm of an isokinetic dynamometer moving at a constant velocity of $90°\cdot s^{-1}$. Specific variables that were assessed were before, immediately after, and for 5 days after exercise were maximal voluntary isometric and isokinetic torque, range of motion, upper arm circumference, plasma creatine kinase activity, and muscle soreness. Results suggest the trained group showed significantly smaller changes in all of the measures except for muscle soreness and faster recovery of muscle function compared with the untrained group. These results suggest that resistance-trained men are less susceptible to muscle damage induced by maximal eccentric exercise than untrained subjects.

Newton, R. U., et al., Effects of ballistic training on preseason preparation of elite volleyball players.

The purpose of this study was to determine whether ballistic resistance training would increase vertical jump performance of already highly trained jump athletes. Male volleyball players from a NCAA Division I team participated in the study. Standing vertical jump and reach along with jump and reach from a three-step approach were measured. Several types of vertical jump tests were also performed to measure force, velocity, and power production during vertical jumping. All participants completed the usual preseason volleyball on-court training combined with a resistance training program and were split into a treatment and control group. The treatment group completed 8 weeks of squat jump training while the control group completed squat and leg press exercises. Both groups were retested at the completion of the training period. The treatment group produced a significant increase in both types of jumps. These increases were significantly greater compared to the control group who did not observe any differences from pre to post testing. The authors observed that ballistic resistance-training increased overall force output during jumping, and in particular increased rate of force development were the main contributors to the increased jump height. The results of this study offer support to the effectiveness of ballistic resistance training for improving vertical jump performance in elite jump athletes.

Newton, R. U., et al., Mixed-methods resistance training increases power and strength of young and older men.

This study investigated the effects of mixed-methods resistance training on young and older men to determine whether similar increases in muscle power would occur. Specifically, 10 weeks of a periodized resistance-training program was designed to increase muscle size, strength, and maximal power for isometric squat strength, time course of force development, muscle fiber characteristics, and muscle activation (iEMG), as well as force and power output during squat jumps, were compared in young (YM) and older men (OM). Isometric squat strength was higher in the YM compared with OM at all testing occasions and increased over the training period. The early phase of the force-time curve was shifted upward in both groups over the course of the training. During the squat jumps, the YM produced higher force and power at all test occasions and at all loads tested compared with the OM. Both the YM and OM group increased power output for the 17 kg, and 30% and 60% 1RM loads. Although the results of this study confirm age-related reductions in muscle strength and power, the older men did demonstrate similar capacity to young men for increases in these variables.

Nguyen, D., et al., Effect of delayed-onset muscle soreness on elbow flexion strength and rate of velocity development.

Eccentric muscle actions have been shown to induce muscle damage and lead to delayed-onset muscle soreness (DOMS), which may impair performance. The purpose of this study was to examine the effect of DOMS on elbow flexion strength and RVD. Participants performed 6 tests (pre- and post-eccentric and every 24 hours for 4 days). In the pre-eccentric tests, each participant did 5 concentric repetitions of EF/EE on an isokinetic dynamometer at $240°\cdot s^{-1}$. Each subject then completed 6 sets of 10 eccentric EF actions at $30°\cdot s^{-1}$ and finished with a post-eccentric test with another 5 concentric repetitions at $240°\cdot s^{-1}$. On days 1-4, each participant did 5 more repetitions at $240°\cdot s^{-1}$. PT scores on the post-eccentric test and day 1 were both significantly less than on the pre-eccentric test. The RVD scores on the post-eccentric test, day 1, and day 2 were all significantly less than on the pre-eccentric test. From these results the authors suggest that muscle damage and soreness (DOMS) may cause significant decreases in elbow flexion concentric strength and RVD.

Paasuke, J., et al., Neuromuscular fatigue during repeated exhaustive submaximal static contractions of knee extensor muscles in endurance-trained, power-trained and untrained men.

The purpose of this study was to investigate the neural and muscular changes during fatigue produced in repeated exhaustive submaximal static contractions in subjects with different physical training status. Three groups of differently adapted male subjects (power-trained, endurance-trained and untrained) performed 10 sets of repetitive submaximal isometric contractions at 40% of their maximal voluntary contraction (MVC) force till exhaustion was achieved. One minute rest periods were allowed between each set. Results indicate that the endurance-trained athletes had a significantly longer holding times for all 10 trials compared with power-trained athletes and untrained subjects. However, no significant differences in static endurance between power-trained athletes and untrained subjects were noted.

Pereira, M., and Gomes, P., Movement velocity in resistance training.

Recommendations for resistance training include the number of exercises, sets, repetitions, and frequency of training, but ambiguously mention movement velocity. For example, different velocities suggest different performances (i.e. a different number of repetitions or different loads). The authors claims studies investigating the effect of different movement velocities on resistance training have not reached a consensus. Some studies indicate specificity in strength gains while others indicate generality, and that some indicate slow training to be better, while others indicate fast training or indicate no differences. Although a wide variety of instruments were used throughout testing (hydraulic equipment, dynamometer) the results seem to suggest that no differences are observed between velocities. Being able to define the training velocity is mostly important for athletic performances where a wide range of velocities are needed and transfer of gains would greatly optimize training. Furthermore, at the other end of the spectrum, there are the elderly, to whom power loss may impair even daily functions, but training with fast velocities might increase injury risk and, therefore, transfer of gains from slow training would be greatly beneficial.

Stock, M. S., et al., The effects of diverting activities on recovery from fatiguing concentric isokinetic muscle actions.

The purpose of this study was to examine the effects of diverting activities on recovery from fatiguing concentric isokinetic muscle contractions. On 3 separate occasions, participants performed 2 bouts of 50 consecutive maximal concentric isokinetic muscle contractions of the dominant leg extensors. Between these bouts, the participants either performed a mental diverting activity, physical diverting activity, or rested quietly. For each trial, the peak torque data from the first and second bouts of 50 muscle actions served as the pretest (Pre) and posttest (Post) data. The results indicated that when the participants rested quietly or performed the physical diverting activity between the fatiguing bouts, the initial peak torque values observed for Post were significantly less than those for Pre. Participants who performed math problems showed no decline in the initial peak torque values, indicating better recovery. Additionally, a decline in the average torque values was observed from Pre to Post for those who rested quietly, but not for those who had mental or physical diverting activities. No differences were observed among the trials for final peak torque, percent decline, or the linear slope of the decline in peak torque. The authors findings demonstrated that performing either mental or physical diverting activities after fatiguing isokinetic muscle actions enhanced recovery.

Stock, M. S., et al., Sex comparisons for relative peak torque and electromyographic mean frequency during fatigue.

This study compared the relative peak torque and normalized EMG mean frequency (MNF) responses during fatiguing isokinetic muscle actions for men versus women. Subjects performed 50 maximal concentric isokinetic muscle actions of the leg extensors at a velocity of $180°\cdot s^{-1}$ while surface EMG signals were detected from the vastus lateralis, rectus femoris, and vastus medialis. The variables assessed were initial, final, and average peak torque; percent decline; the estimated percentage of fast-twitch fibers for the vastus lateralis; and the linear slope coefficients and y-intercepts for normalized EMG MNF versus repetition number. The mean initial, final, and average peak torque values for men were greater than those for women. There were no mean differences for percent decline and the estimated percentage of fast-twitch fibers for the vastus lateralis. Men demonstrated greater peak torque values than those for women, but the declines in peak torque and normalized EMG MNF were similar between the sexes. The vastus medialis was more fatigue-resistant than both the vastus lateralis and rectus femoris.

Thompson, B. J., et al., Influence of acute eccentric exercise on the H: Q ratio.

The purpose of this study was to examine the effects of an acute bout of eccentric exercise on maximal isokinetic concentric peak torque of the leg flexors and extensors and hamstrings-to-quadriceps (H:Q) strength ratio. Volunteers performed maximal, concentric isokinetic leg extension and flexion muscle actions at $60°\cdot s^{-1}$ before and after (24-72 h) a bout of eccentric exercise. The eccentric exercise protocol consisted of 4 sets of 10 repetitions for the leg press, leg extension, and leg curl exercises at 120% of the concentric one repetition maximum (1-RM). The results indicated that the acute eccentric exercise protocol resulted in a significant decrease in isokinetic leg flexion and leg extension peak torque, 24-72 h post-exercise. However, the H:Q ratios were unaltered by the eccentric exercise protocol. The authors suggested that an acute bout of eccentric exercise utilizing both multi- and single- joint dynamic constant external resistance (DCER) exercises results in similar decreases in maximal isokinetic strength of the leg flexors and extensors, but does not alter the H:Q ratio.

Thompson, B. J., et al., Effects of aging on maximal and rapid velocity capacities of the leg extensors.

The aim of this study was to examine the effects of aging on maximal and rapid velocity characteristics of the leg extensor muscles. Participants performed three leg extension MVCs at $240°\cdot s^{-1}$ and at Vmax. Vmax was calculated as the highest velocity attained during the unloaded MVC and RVD was the linear slope of the velocity-time curve for the contractions. The old men exhibited lower Vmax and RVD values compared to the young men. These lower velocity characteristics for the old men may be attributed to the increased functional limitations often observed in older adults. Further, the present study found that the greater age-related declines for RVD values compared to Vmax, and that this could suggest an enhanced age-related impairment in the ability of the older adults' muscle to generate velocity rapidly versus the ability to generate maximal velocity. The authors suggest these findings highlight the importance of time-dependent velocity measures when assessing the effects of aging on rapid velocity capacities.

Thompson, B. J., et al., Age related differences in maximal and rapid torque characteristics of the leg extensors and flexors in young, middle-aged and old men.

The purpose of this study was to examine the age-related differences in maximal and rapid torque characteristics of the leg extensor and flexor muscle groups in young, middle-aged, and old men. Participants performed MVCs of the leg extensors and flexors. PT was greater in the young and middle-aged when compared to the old men for both muscle groups. Significant decreases in PT in the old men may be largely a function of mechanisms associated with loss of muscle strength and muscle mass.

Thorstensson, A. and Karlsson, J., Fatiguability and fiber composition of human skeletal muscle.

This study was performed to examine the development of fatigue in human skeletal muscle with repeated fast maximal isokinetic contractions, and its relation to fiber composition of the contracting muscle. The fatigability of the quadriceps muscle was investigated in 10 male subjects. Fatigability was assessed as the decline in maximal force (% of initial values) with 50 repeated isokinetic knee-extensions at fast angular velocity (3.14 radis$\cdot s^{-1}$ or180 deg$\cdot s^{-1}$). Every subject was tested on two occasions and the standard deviation for a single determination of fatigability was 1.4%. The decline in force after 50 contractions was on the average about 45%. The individual values varied, however, and a linear correlation was present between fatigability and % FT fibers. The authors concluded that development of fatigue in human skeletal muscle performing repeated fast dynamic contractions with maximal effort was most marked in muscles with a higher proportion FT fiber.

Yoon, T., et al., Fatigability and recovery of arm muscles with advanced age for dynamic and isometric contractions.

This study determined whether age-related mechanisms can increase fatigue of arm muscles during dynamic MVCs, as it occurs in the lower limb. These authors compared EF fatigue of young and old men during and in recovery from a dynamic and an isometric postural fatiguing task. Each task was maintained until failure while supporting a load equivalent to 20% of MVC torque. Transcranial magnetic stimulation (TMS) was used to assess supraspinal fatigue (superimposed twitch, SIT) and muscle relaxation. Observations for this study showed that it took longer for old men to fatigue compared to younger men for isometric contractions, however no differences were observed for dynamic contractions. Initial peak rate of relaxation was slower for the old compared to the young men, and was associated with a longer time to failure for both tasks. Low initial power during EF was associated with the greatest reduction in time to failure between the isometric task and the dynamic task. SIT declined after both fatigue tasks similarly with age, although the recovery of SIT was associated with MVC recovery for the old (both sessions) but not for the young men. Biceps brachii and brachioradialis EMG activity (% MVC) of the old men were greater than that of the young men during the dynamic fatiguing task, but were similar during the isometric task. Muscular mechanisms and greater relative muscle activity explain the greater fatigue during the dynamic task for the old men compared with the young men in the EF muscles. Recovery of MVC torque however relies more on the recovery of supraspinal fatigue among the old men than among the young men.

D. IRB MATERIALS

Oklahoma State University Institutional Review Board

Date:	Thursday, November 19, 2015
IRB Application No	ED15153
Proposal Title:	Effects of a dynamic isokinetic protocol on strength characteristics in the upper and lower extremity between traditional and explosive resistance trained males
Reviewed and Processed as:	Expedited

Status Recommended by Reviewer(s): Approved Protocol Expires: 11/18/2016

Principal
Investigator(s):

Cameron S. Mackey	Mitchel Magrini	Jason DeFreitas
192 CRC	1323 E Cedar Dr	198 CRC
Stillwater, OK 74078	Stillwater, OK 74075	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1.Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms
2.Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3.Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4.Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

INFORMED CONSENT FOR PARTICIPATION IN THE STUDY

Project Title: Effects of fatigue on force and muscle activation characteristics between traditional and explosive resistance-trained males

Investigators: Cameron Mackey, B.S.
Mitchel Magrini, MSc
Jason DeFreitas, PhD
School of Applied Health and Educational Psychology
Oklahoma State University

Purpose: Variations in resistance training methodologies may elicit different adaptations within skeletal muscle. An adaptation to resistance training may be the increase of a muscle's ability to resist fatigue and contract maximally and explosively. Additionally, the specific differences in the types (i.e., traditional vs. explosive) of resistance training as well as the muscle trained (i.e., upper extremity vs. lower extremity) may elicit differential adaptations in the ability of the muscle to perform maximally after exercise-induced fatigue. Therefore, the purpose of this study is to examine fatigue resistance as well as maximal and rapid strength characteristics of the upper and lower extremities between traditional and explosive resistance trained males following dynamic muscle actions.

Inclusion Criteria: Males aged 18-35 years of age. Must resistance train 3 times per week or more, for the past 6 months (This information will be obtained from your health history questionnaire on the familiarization day).

Exclusion Criteria: Any previous (past 3 months) or ongoing muscle or bone conditions. Any participant that has any absolute or relative contraindication to exercise testing as detailed by the American College of Sports Medicine guidelines will not be allowed to participate.

Procedures:

- As a participant you will be asked to visit the lab on 2 occasions, for a total of 2 hour over the course of 1 week.
- You will be asked to wear shorts, t-shirt, and closed toed athletic tennis shoes every time you come to the lab
- An appointment would be scheduled with individuals interested in participating. The PI or co-PI would meet with these individuals to answer any questions, and subsequently obtain consent if individuals want to participate. Participants would perform testing sessions in the Applied Musculoskeletal and Human Physiology Research Lab at Oklahoma State University – Stillwater Campus. Prior to any data collection, each participant will be required to sign an informed consent document, a health history questionnaire, and a physical activity readiness questionnaire (PAR-Q). The health history questionnaire PAR-Q will provide us with detailed information regarding each participant's current health and physical activity status from which we can determine their eligibility to participate in this study. Following completion of informed consent and other documentation the following measurements will take place during the first visit prior to experimental testing. Anthropometric Measurements: height, weight, circumferences, and skin folds (measure the thickness of skin) of the triceps, biceps, forearms, chest/pectoral, abdominals, thigh, and calves will be completed. Additionally, Ultrasonography Measurements, utilizing a diagnostic ultrasound device, will be used to measure the muscle architecture of the biceps, triceps, quadriceps, and hamstrings. For each assessment, you will lay/sit in either a supine/seated position on a cushioned plinth or chair. Water-soluble gel will be placed on the surface of the skin at the site of each muscle prior to the assessment in order to avoid compression or depression of the muscle. During assessment, a probe connected to the ultrasound device will be placed on the skin at the site of each muscle to view and capture images in both transverse and longitudinal planes.
- All participants will warm-up on a cycling ergometer at 50 RPM for 5 minutes, after the warm-up, EMG sensors will be placed on the surface of the skin above the biceps brachii, triceps brachii, vastus lateralis, and biceps femoris to measure how active the muscle is. Prior to EMG placement, the skin will be shaved above the biceps brachii, triceps brachii, vastus lateralis, and biceps femoris with a razor, lightly abraded, and cleaned with isopropyl alcohol. After EMG placement, measurements will be assessed on a Biodex dynamometer using the flexors and extensors of the knee and elbow. Participants will be strapped into the dynamometer to enhance stability (straps will be placed across each side of the chest, across the waist, and across the right thigh) prior to performing the protocol. The participant will be randomly assigned to complete the fatigue protocol of the knee or elbow muscles first. Upon completion of the first assigned protocol, the participant will have a 20 minute rest period and then complete the other. Prior to starting and immediately after completing the fatigue protocol participants will perform maximal voluntary contractions for each of the knee and elbow flexors and extensors. The fatigue protocol will consist of 50 repetitions of dynamic isokinetic contractions at 180°/s (medium velocity) for both the upper extremity (elbow extensors/flexors) and lower extremity (knee extensors/flexors). Grip strength will be assessed prior to and immediately after the upper extremity fatigue protocol using a hand held grip strength dynamometer. For testing sessions: participants will be strongly encouraged to verbally express to the PI or advisor at any time if they are experiencing any lightheadedness, pain, or any other physical problems during testing or as a result of the study.

Risks of Participation: The testing that will be implemented for the current study are greater than the physical requirements normally performed during routine physical tasks. The physical demands of the tests will be similar to a very short conventional exercise workout and the physical stress will likely be similar to what the participants have experienced during an exercise routine. The soreness that may be felt after the exercise is known as delayed onset muscle soreness (DOMS). Medical records will only be used during the screening process. In case of injury or illness resulting from this study, emergency medical treatment will be available from OSU Health Services or Stillwater Medical Center. No funds have been set aside by Oklahoma State University to compensate you in the event of illness or injury. It is important to note that you are free to withdraw from the study at any time without prejudice or penalty.

Confidentiality: All recorded data will be matched with the subject's name until the completion of all data collection. Confidentiality will be maintained by coding all data forms with individual identification numbers. All coded data forms will be locked in the PI's office (CRC 196) in a locked file cabinet. Electronic coded data will be stored on a password protected thumb drive that will be locked in the PI's office. The health history questionnaire and consent forms will be stored separately from coded data in a locked filing cabinet in the Applied Musculoskeletal & Human Physiology Research Laboratory (CRC 192). The signed consent forms will be kept for 3 years per federal guidelines. All data forms and health history questionnaires will be shredded upon completion of the study. Participants will be assigned an ID number. The key with names and numeric identifiers will be stored on a password locked computer that is not accessible to anyone other than the primary investigator. Health history questionnaires and consent forms will contain names but no ID numbers.

"The records of this study will be kept private. Participants' names will be kept separate from their data by assigning a numeric identifier. The key with names and numeric identifiers will be stored on a password locked computer that is not accessible to anyone other than the primary investigator. Research records will be stored securely and only researchers and individuals responsible for research oversight staff will have access to the records. All data forms will contain a unique code given to you, and will be secured separately from the health history questionnaire and consent form. It is possible that the consent process and data collection will be observed by research oversight staff responsible for safeguarding the rights and wellbeing of people who participate in research. Any written results will discuss group findings and will not include information that will identify you".

Contacts: This study has been reviewed and approved by the Oklahoma State University Review Board (IRB). If you have questions about the research project you may contact Cameron Mackey, B.S. cameron.mackey@okstate.edu or Mitchel Magrini, MSc, at mitchel.magrini@okstate.edu. If you have questions about your rights as a research volunteer, you may contact Hugh Crethar by phone 405-744-9442 or email crethar@okstate.edu or the IRB office, 223 Scott Hall, Stillwater, OK 74078, 405-744-3377, irb@okstate.edu.

Signatures:

I have read and fully understand the consent form. I sign it freely and voluntarily. A copy of this form has been given to me.

Signature of Participant   Date

I certify that I have personally explained this document before requesting that the participant sign it.

Signature of Researcher   Date

PRE-EXERCISE TESTING HEALTH & EXERCISE STATUS QUESTIONNAIRE

OKLAHOMA STATE UNIVERSITY
DEPARTMENT OF HEALTH AND HUMAN PERFORMANCE

RECRUITMENT NO.____________

Name ____ Date____________

Work Phone ____________________ Home Phone (Cell)____________________

E-mail address______________________________

Person to contact in case of emergency____________________________

Emergency Contact Phone ____________________

Gender________ Age ______(yrs) Height ______(ft)______(in) Weight______(lbs)

A. JOINT-MUSCLE STATUS (✓Check areas where you currently have problems)

Joint Areas
( ) Wrists
( ) Elbows
( ) Shoulders
( ) Upper Spine & Neck
( ) Lower Spine
( ) Hips
( ) Knees
( ) Ankles
( ) Feet
( ) Other____________________

Muscle Areas
( ) Arms
( ) Shoulders
( ) Chest
( ) Upper Back & Neck
( ) Abdominal Regions
( ) Lower Back
( ) Buttocks
( ) Thighs
( ) Lower Leg
( ) Feet
( ) Other____________________

B. HEALTH STATUS (✓Check if you currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction
( ) Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( ) Arthritis or Gout
( ) Edema
( ) Epilepsy
( ) Multiply Sclerosis
( ) High Blood Cholesterol or Triglyceride Levels
( ) Allergic reactions to rubbing alcohol

( ) Acute Infection
( ) Diabetes or Blood Sugar Level Abnormality
( ) Anemia
( ) Hernias
( ) Thyroid Dysfunction
( ) Pancreas Dysfunction
( ) Liver Dysfunction
( ) Kidney Dysfunction
( ) Phenylketonuria (PKU)
( ) Loss of Consciousness

C. PHYSICAL EXAMINATION HISTORY

Approximate date of your last physical examination__________________________

Physical problems noted at that time__________________________________

Has a physician ever made any recommendations relative to limiting your level of physical exertion? _________YES _________NO
If YES, what limitations were recommended?____________________________
____

RECRUITMENT NO.____________

D. CURRENT MEDICATION USAGE (List the drug name and the condition being managed)

MEDICATION	CONDITION
____________________	____________________________
____________________	____________________________
____________________	____________________________

E. PHYSICAL PERCEPTIONS (Indicate any unusual sensations or perceptions. ✓Check if you have recently experienced any of the following during or soon after *physical activity* (PA); or during *sedentary periods* (SED))

PA	SED		PA	SED	
( )	( )	Chest Pain	( )	( )	Nausea
( )	( )	Heart Palpitations	( )	( )	Light Headedness
( )	( )	Unusually Rapid Breathing	( )	( )	Loss of Consciousness
( )	( )	Overheating	( )	( )	Loss of Balance
( )	( )	Muscle Cramping	( )	( )	Loss of Coordination
( )	( )	Muscle Pain	( )	( )	Extreme Weakness
( )	( )	Joint Pain	( )	( )	Numbness
( )	( )	Other____________________	( )	( )	Mental Confusion

F. FAMILY HISTORY (✓Check if any of your blood relatives . . . parents, brothers, sisters, aunts, uncles, and/or grandparents . . . have or had any of the following)

( ) Heart Disease
( ) Heart Attacks or Strokes (prior to age 50)
( ) Elevated Blood Cholesterol or Triglyceride Levels
( ) High Blood Pressure
( ) Diabetes
( ) Sudden Death (other than accidental)

G. EXERCISE STATUS & SUPPLEMENTATION

Do you regularly lift weights (3 or more times per week)? **YES** **NO**

How long have you engaged in this form of exercise? ______ years ______ months

How many days per week do you lift? _______ days

Would you classify yourself as a <u>traditional</u> weight lifter (i.e., squat, bench, deadlift, etc.)? **YES** **NO**

How long have you engaged in this form of exercise? ______ years ______ months

How many days per week do you traditionally resistance train? ______ days

Would you classify yourself as an <u>explosive</u> weight lifter (i.e., snatch, clean, jerk, etc.)? **YES** **NO**

How long have you engaged in this form of exercise? ______ years ______ months

How many days per week do you explosively resistance train? ______ days

Are you currently taking any supplements (i.e., caffeine, creatine, protein, etc)? **YES** **NO**

Please list:

Please describe a typical/general day of resistance-training and include volume (sets x reps x exercises):

Please ✓all of the exercises you regularly perform.

( ) Bench Press
( ) Chest Fly's
( ) Shoulder Press
( ) Seated Row
( ) Lat Pulldowns
( ) Bent Over Rows
( ) Bicep Curls

( ) Triceps Extensions
( ) Pullups
( ) Pushups
( ) Hang Cleans
( ) Cleans
( ) Power Cleans
( ) Clean & Jerk

( ) Snatch
( ) Push Press
( ) Dips
( ) Lateral Raises
( ) Dumbbell Rows
( ) Crunches
( ) Situps

( ) Squat
( ) Jump Squat
( ) Leg Press
( ) Step Ups
( ) Box Jumps
( ) Lunges
( ) Split Jumps

( ) Leg Extensions
( ) Leg Curls
( ) Calf Raises
( ) Deadlifts
( ) RDL
( ) Good Mornings
( ) Kettle Bell Swings

( ) Sled Prints
( ) Sled Pulls
( ) Muscle Ups
( ) Tire Flip
( ) Hand Stand Push up
( ) Rope Climb
( ) Thrusters

( ) Other - Please List:

VERBAL SCRIPT FOR SUBJECT RECRUITMENT

Name of Study: Effects of a dynamic isokinetic protocol on strength characteristics in the upper and lower extremity between traditional and explosive resistance trained males

Hi, my name is Cameron Mackey (and / or name of other involved researcher). We are currently recruiting subjects for a study in the Exercise Physiology Laboratory. The purpose of this study is to examine fatigue resistance as well as maximal and rapid strength characteristics of the upper and lower extremities between traditional and explosive resistance trained males following dynamic muscle actions.

To do this, you will have report to the lab 2 total times, separated by 48-72 hours between each testing session. The methods used will involve measuring maximal strength characteristics and fatigue index of your upper and lower extremity on a biodex dynamometer. Your measurements will be recorded on the second day of the study.

Inclusion criteria: Males aged 18-35 years of age. Must resistance train 3 times per week or more, for the past 6 months (This information will be obtained from your health history questionnaire on the familiarization day).

Exclusion criteria: Any previous (past 3 months) or ongoing muscle or bone conditions. Any participant that has any absolute or relative contraindication to exercise testing as detailed by the American College of Sports Medicine guidelines will not be allowed to participate.

All risks and benefits of participation in this study and your rights as a research participant will be described in the consent form provided at the first session before testing begins. You will be required to sign this in order to show that you understand all that is contained in this form. As a participant, you will be contributing to the understanding of dynamic strength characteristics and fatigue resistance of the upper and lower extremity muscles. If you decide you do not want to participate at any time, you may drop out with no consequence. If you are interested and would like to set up times for participation or have any questions, please email Cameron Mackey at cameron.mackey@okstate.edu. If you would like to speak to my advisor or have any concerns, please contact Dr. Doug Smith at 405-744-5500.

Human Performance Study

Health and Human Performance Laboratory is investigating the **effects of a dynamic isokinetic protocol on strength characteristics in the upper and lower extremity between traditional and explosive resistance trained males.** Participants will be used in determining the fatigue resistance as well as maximal and rapid strength characteristics in an upper and lower body functional assessment.

If you fit the criteria below and want to volunteer:

- ✓ **No previous (3 months) or on going muscle or bone conditions**
- ✓ **No Heart, Muscular, Nervous system Disorder/Condition**
- ✓ **Resistance trained ≥3x/week for the past 6 months**

Potential **benefits** include:

- ✓ **Knowledge of Thorstensson Protocol**
- ✓ **Dynamic Movement Assessment**
- ✓ **Functional Performance Assessment**
- ✓ **Fiber Typing**
- ✓ **Upper Body Strength Measurement**
- ✓ **Lower Body Strength Measurement**

Testing sessions will be scheduled at your convenience.

Contact: Cameron Mackey at **cameron.mackey@okstate.edu**

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Cameron Mackey cameron.mackey@okstate.edu

Recruitment No. ____________ Date ____________ Dominant Limb____________

Grip Strength D1__________ D2pre__________ D2post__________

PRE_UE:

Isometric: Biceps: 90° / Triceps: 90°

Flexors (Biceps) ____________________ File No.

____________________ File No.

Extensors (Triceps) ____________________ File No.

____________________ File No.

Isokinetic: Flexors (Biceps)

500°/sec ____________ File No. ____________ File No.

Isokinetic: Extensors (Triceps)

500°/sec ____________ File No. ____________ File No.

PROTOCOL: ____________ **File No.**

POST UE:

Isometric: Biceps: 90° / Triceps: 90°

Flexors (Biceps) ____________________ File No.

____________________ File No.

Extensors (Triceps) ____________________ File No.

____________________ File No.

Isokinetic: Flexors (Biceps)

500°/sec ____________ File No. ____________ File No.

Isokinetic: Extensors (Triceps)

500°/sec ____________ File No. ____________ File No.

GC: ____________ File No.

Recruitment No. ____________ Date ____________ Dominant Limb____________

PRE_LE:

Isometric: Quads: 120° / Hams: 150°

Extensors (Quad) ____________________ File No.

____________________ File No.

Flexors (Ham) ____________________ File No.

____________________ File No.

Isokinetic: Extensors (Quad)

500°/sec ____________ File No. ____________ File No.

Isokinetic: Flexors (Ham)

500°/sec ____________ File No. ____________ File No.

PROTOCOL: ____________ **File No.**

POST LE:

Isometric: Quads: 120° / Hams: 150°

Extensors (Quad) ____________________ File No.

____________________ File No.

Flexors (Ham) ____________________ File No.

____________________ File No.

Isokinetic: Extensors (Quad)

500°/sec ____________ File No. ____________ File No.

Isokinetic: Flexors (Ham)

500°/sec ____________ File No. ____________ File No.

GC: ____________ File No.

VITA

Cameron Shane Mackey

Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF FATIGUE ON STRENGTH AND RAPID FORCE CHARACTERISTICS BETWEEN TRADITIONAL AND EXPLOSIVE RESISTANCE-TRAINED MALES

Major Field: Health and Human Performance

Academic Qualifications

Bachelor of Science in Health Education and Promotion May 2014
Oklahoma State University – Stillwater, Oklahoma

Associates of Applied Science Degree in Construction Technology May 2010
Community College of the Air Force – Montgomery, Alabama

Professional Appointments- Academia

Graduate Teaching/Research Assistant Spring 2015 – Spring 2016
Oklahoma State University – Stillwater, Oklahoma State University

- HHP 4773 Principles of Exercise Testing and Prescription Lab (Spring 2016)
- HHP 3114 Physiology of Exercise Lab (Spring 2015, Summer 2015, Fall 2015)
- HHP 2654 Applied Anatomy Lab (Fall 2015, Spring 2016)
- HHP 3010-503 Sport Supplements for Human Performance (Summer 2015)
- HHP 2802 Medical Terminology for Health Professionals (Online) (Spring 2015, Summer 2015, Fall 2015)

Professional Appointments- Field Experience

Internship – Chief Wellness Officer Spring 2014
Oklahoma State University – Stillwater, Oklahoma

- +400 hours working with Dr. Suzy Harrington
- Assisted with researching, compiling, and analyzing health data
- Helped plan and market events at OSU including the walking trails grand opening